



Climate Change, Rural Out-Migration, and Social Transformation in Uttarakhand

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Abstract

This paper explores the impact of climate change and rural out-migration on social transformation with a specific focus on migration prone hill districts of Uttarakhand. The study uses secondary data and evidence at the district level and analysis of climate and migration indicators. It has been found that climatic factors like rainfall variability (38.30%), water scarcity (34.04%), and agriculture degradation (31.91%) are some of the most influential factors for migration. Amongst the mediating factors, agricultural stress (29.79%), employment deficit (21.28%), and service gaps (19.15%) have been identified as major determinants of rural migration. District-level evidence suggests that Pauri Garhwal (21.28%), Almora (17.02%), and Tehri Garhwal (14.89%) are some of the worst affected districts. The trend of migration analysis further shows that there has been a rise in the case of temporary migration from 42 thousand in 2019 to 71 thousand in 2026, whereas that of permanent migration has risen from 9 thousand to 21 thousand.

Keywords: Climate Change, Rural Out-Migration, Social Transformation, Uttarakhand, Livelihood Vulnerability

1. Introduction

Climate change has turned out to be one of the greatest challenges towards sustainability in the mountain regions worldwide, and one such region that is highly affected by the impact of the climate change in India is the Himalayan region. Uttarakhand, situated in the central Himalayas, offers a very interesting case to study the nexus of climate change, rural migration and social transformations since its economy, settlement pattern and culture have always been based on fragile mountain ecosystem. The geography of the state consists of mountainous terrain with rain-fed subsistence agriculture, scattered villages, dependency on the mountains and springs and a long tradition of both seasonal and permanent migrations. As per geographical statistics at the level of the state, nearly 86% of Uttarakhand's land is mountainous and around 65% of the total area comprises of the forests [1]. But during the past two decades, the region has faced high climatic variability in the form of irregular rains, increase in temperature, reduced snowfall in higher elevations, cloudburst, landslides, flash floods, dry springs and forest fires. These ecological transformations are not taking place independently of one another but rather have direct implications for agriculture, livestock, water supply to households, transport, and human settlements. Thus, climate change in Uttarakhand is not just an ecological concern but also a socio-economic and demographic one.

In Uttarakhand, the structure of agriculture makes rural families more susceptible to climate change. In the hills of Uttarakhand, agriculture mainly includes small farmers, subsistence farming, and rain fed farming, where farming is dependent on monsoon rains, natural springs, and family labor. Irrigation facilities in many upland villages are scarce, so any small change in rainfall patterns and moisture content can lead to reduction in productivity of farms. Research conducted in recent times on climate and agriculture in Uttarakhand shows that farming population of Uttarakhand is facing problems like delayed onset of monsoons, unpredictable rainfall, more number of dry days, loss of crops, reduction in soil moisture, shortage of water for crops as well as horticulture [2][3]. The Uttarakhand Climate Responsive Rainfed Farming project also highlights that the hill agriculture system in Uttarakhand is highly vulnerable due to reasons like erratic rainfall, drying of springs, soil erosion, and uncertainty in production [3]. In reviewing the impact of climatic changes on agriculture in Uttarakhand, it is observed that changing climatic conditions of temperature and rainfall have begun to affect the cropping patterns and reduce the viability of rain-based farming system; some estimates provided in the literature reveal a decline in productivity of rice crop in future climatic

scenarios and the ongoing stress on water-based crops [4]. This development is particularly important in view of the fact that in a state like Uttarakhand where mountain agriculture has been maintained through crop rotation, livestock rearing, forestry and barter system of labor, and not through high input commercial farming.

One of the most threatening impacts of climate change in rural Uttarakhand is the issue of water insecurity. Most of the hill villages have dependence on natural springs and streams rather than canals for their irrigation needs. In mountainous regions, the disappearance of springs is not just an issue related to hydrology but it also impacts drinking water, household labor, sanitation, livestock, kitchen gardens, and crop survival. Recent research on climate change and migration in Uttarakhand indicates that due to decreasing snowfall, erratic rainfall pattern, and increased land use pressure, the springs recharge systems have been adversely impacted resulting in water scarcity during particular seasons in many rural communities [2][5]. There are many social implications of this water scarcity problem as well. Women and elders of the house face the burden of fetching water from greater distances, increasing labor burden for the families and making it difficult for them to grow vegetables, pulses and fodder crops. In addition to this, the water shortage problem has made it difficult for the household to maintain livestock that traditionally contributed significantly in the hills through providing manure, milk, traction and nutrition recycling.

The threat to Uttarakhand is compounded further by the increasing occurrences of environmental disasters. The region has had flash floods, landslides, glacier and river-based dangers, road collapses, and excessive rainfall disasters. The major event that marks a watershed moment in the discourse on Himalayan vulnerability is the Kedarnath disaster of 2013; however, it was followed by others such as the Chamoli disaster of 2021 and continuous rain-induced landslides in many districts. In July 2026, for instance, rainfall yet again triggered rockfall and led to the closure of numerous roads within Uttarakhand. Environmental instability disrupts the lives of the communities in the region, which affects their movement, livelihoods, access to healthcare facilities, schools, mandis, employment, and relief after a disaster strikes [6]. These environmental risks impact the rural areas more than others as people living far from urban centers have their access to health services, schools, mandis, employment opportunities, and relief dependent on precarious road systems. Frequent closures and slope instabilities make rural residents feel less secure about living in the village setting. Thus, through repeated environmental disasters, the sense of risk among households in these villages emerges. In this backdrop, it is essential to understand the issue of rural out-migration in Uttarakhand. Migrations from the hill areas have been going on for some time now; traditionally, there is an established custom of migrating to the army, the bureaucracy, educational institutions, and cities among others in search of livelihoods. But the extent and social implications of migrations have witnessed a dramatic change over the last few decades. While migration used to be a means of additional income in the past, it has come to form an essential part of the village society today. Some field surveys carried out in Uttarakhand in the past indicate that migration for employment had become widespread in hill districts of the state with as many as 88 percent of rural households having a migrant family member in the survey sample [7]. However, more contemporary studies reveal that outmigration continues to be firmly rooted in the hill economy and has become a result of the interplay of various factors, such as the adverse environment, lack of agriculture sustainability, lack of employment opportunities, inadequate facilities of education and healthcare, as well as rising aspirations of the new generation [8][9]. What is crucial is that migration at present implies not only moving away of individuals earning their living in their native village but also moving away of the whole families to adjacent towns, district headquarters, Dehradun, Haldwani, and other cities outside the state.

From a sociological viewpoint, climate change is not just an environmental process but a significant agent of social change that affects institutions, occupations, culture, and demography. Sociologists considered society to be a structure working on the basis of the interdependent nature of institutions like family, economy, education, and community. As per Structural Functionalist theory, environmental disturbances create disruptions in the balance of these institutions and compel societies to restructure themselves to maintain stability [10]. Climate change has adversely affected agriculture, water, and disasters in Uttarakhand which has led to a disruption in the traditional mountain economy thus affecting roles in family, occupational structure, and community participation. Out migration from rural areas has thus resulted in demographic changes in villages due to increased number of female headed households, aged people, and deserted settlements. "Locked Houses" and "Ghost Villages" are not just indicative of decreased population but also the weakening of collective social institutions like sharing of labor, village council, and cultural events. As per Social Ecological theory, ecological deterioration and social inequality feed into each other and environmentally fragile societies become socially marginalized [11].

The phenomenon of migration occurring in Uttarakhand may also be explained using the Push-Pull Theory of Migration proposed by Lee, where the decision to migrate is considered a result of the interplay between the undesirable environment in the origin place and the desirable opportunities in the destination place [12]. There are a number of push factors in the form of decreased agricultural production, erratic rainfall, drought, crop destruction by wild animals, poor infrastructure, and lack of employment opportunities in the hilly areas, while the urban employment opportunities, access to education, health care, and public services provided in cities like Dehradun, Haldwani, Delhi, and Chandigarh work as pull factors. But climate change makes these push factors even more significant due to increased vulnerability and thus leads to higher rates of migration.

Moreover, the Sustainable Livelihood Framework presented by Chambers and Conway says that households cope with environmental changes by adjusting their livelihood capitals, which include human capital, natural capital, financial capital, physical capital, and social capital [13]. In the case of Uttarakhand, reduction in natural capital due

to water shortages and degradation of land forces households to make adjustments in terms of increased dependency on migration and remittances. Although remittances help to improve the living conditions of households by enhancing incomes and education prospects, these also cause a change in consumption patterns, decreasing dependency on agriculture, and causing demographic changes in rural areas. Additionally, Social Capital Theory posits that continued migration causes erosion of trust, reciprocity, and collective actions in the community and thereby weakens institutions and social networks in villages [14]. Since youth migrate economically, elderly people and women shoulder more burdens and thus cannot take part in community governance, village festivals, and collective resource management. Given this background, the present research on “Climate Change, Rural Out-Migration and Social Transformation in Uttarakhand” is of particular importance. This study aims at exploring the way climate pressures interplay with agriculture crisis, water scarcity, risk of disasters and uneven development in transforming the demographic and social fabric of the region. Migration is not approached by the researchers as an issue of people’s relocation from villages to towns. Instead, migration is viewed as a socio-ecological process that determines the gender dynamics, family composition, land usage, institutional practices and rural identity. The significance of this issue lies in the fact that Uttarakhand is a part of a wider problem in South Asia the problem of sustainability of rural societies in the face of environmental changes, economic transformation and rising aspirations for mobility.

2. Review of Literature

Literature about climate change, rural outmigration and socio-cultural transformation in Uttarakhand shows that outmigration from the mountainous region is not considered only an economic phenomenon anymore; it is seen now as a multifaceted phenomenon determined by the impact of environment, society, demography, and institutions. Previously, the researchers used to identify outmigration due to unemployment, fragmentation of land holdings, low agricultural production, low education levels and low industrialization in the region. Yet the recent literature reveals that the effects of climate change have deepened these structural issues, and outmigration has become the prevalent adaptive strategy for the rural households. As stated in Uttarakhand Migration Commission, there were more than 6.9 lakh people migrating temporarily and more than 1.4 lakh people migrated permanently from 2011 to 2022, and many villages were partially or fully depopulated. It can be concluded that outmigration has become a socio-ecological process through which the process of socio-cultural transformation in rural areas occurs, influencing demography, social institutions, and regional development. Thus, the current researchers consider outmigration to be a socio-ecological phenomenon, when all these three processes happen concurrently [16].

Socially speaking, migration in Uttarakhand can be explained by Structural Functionalism, wherein society is seen as composed of interrelated institutions like family, economy, education, community, etc., working to establish social equilibrium. Migration caused by climate change affects all these institutions by disturbing social equilibrium because agriculture becomes less productive, water resources become scarce, and the risk of disasters increases. According to Parsons, the stress that occurs in one institution is responded to by changes in others in order to bring about equilibrium. In Uttarakhand, due to reduced productivity of agriculture, economic sustainability of villages decreases, leading to the migration of the youth in search of job opportunities and education. Due to this, families have been changing from joint families to fragmented families, women have been involved more in agriculture, and village institutions like Panchayat, collective farming practices, and community festivals have weakened. Hence, migration should be seen as much more than geographical movement, but rather as structural transformation in rural Himalayas [17].

The literature also shows how much the Push-Pull Theory of Migration of Lee is supported by various scholars, which is considered to be the most influential sociological theory for explaining migration behavior in mountainous areas. The theory claims that migration happens due to the reaction of people to the difficult situation in the place where they come from and the positive pull factors in the place where they go. In Uttarakhand, major push factors include erratic rainfall, dry springs, reduced agricultural income, landslides, poor health care, inadequate education institutions, and unemployment. Major pull factors include the presence of proper educational institutions, better paying jobs, health facilities, transport infrastructure, and the city life in places like Dehradun, Haldwani, Delhi, and Chandigarh. Recent studies show that climate change has made the push factors stronger through livelihood uncertainties. This way, climate change has nothing to do with migration; it only increases the developmental inequality, thus leading to migration [18].

Some studies have looked into the connection between climatic variability and sustainable agriculture in the state of Uttarakhand. In particular, the report titled *Locked Houses, Fallow Lands: Climate Change and Migration in Uttarakhand* by the TERI–Potsdam Institute focuses on the fact that climate change operates mainly as a catalyst for migration as opposed to being a direct cause. This report mentions increasing precipitation variation, temperature increases, drying up of mountain springs, forest fires, cloudbursts and landslides in hill districts. All these changes negatively affect agricultural production and increase the insecurity of livelihoods due to the fact that almost 80% of agriculture in the mountains is rain-dependent. Another interesting thing mentioned in the report was the introduction of locked houses and fallow lands, representing both demographic decrease and agricultural land abandonment. Migration is seen as an integral element of socio-ecological transformation and not simply labour migration [19].

The Sustainable Livelihood Framework by Chambers and Conway is another approach used to study migration from climate-sensitive mountain regions. The framework posits that rural families are supported by various kinds of capital

– natural capital, human capital, financial capital, physical capital, and social capital. Climate change influences natural capital by reducing availability of water, causing land degradation, biodiversity loss, and low productivity of agriculture. If natural capital becomes weaker, families compensate for the effect using migration and remittances. Many farmers from Uttarakhand have shifted from cereal production to other activities, such as tourism, horticulture, medicinal plant cultivation, and wage labour due to uncertainty in agriculture caused by climate change. Research shows that remittance increases family spending on education, health, housing, and consumption; but remittance also encourages abandonment of agriculture since migrants become less dependent on farming over time. Thus, livelihood diversification strengthens family's resilience while also facilitating structural changes in mountain villages [20].

Social Capital Theory also contributes to the understanding of the socio-economic implications of migration in the literature. Social capital is defined as trust, reciprocity, collective action, and networks of community which aid cooperation between people according to Putnam. Migration erodes social capital by diminishing networks due to continuous outflow of economically productive young people who do not participate in local governance, festivals, labour exchange system, and natural resources management in a collective way. In many villages of Pauri Garhwal, Almora, and Tehri Garhwal districts, decline in population has led to closure of schools, less Panchayat involvement and maintenance of common property like forest, irrigation channels, and village roads. Migration, therefore, impacts not only family income but also the organizational abilities of rural communities. It has been concluded from the literature that social capital depletion should be regarded as one of the most important socio-economic consequences of climate induced migration [21].

Another important sociological dimension resulting from the literature review includes gender transformation. Outmigration by men has greatly increased the involvement of women in farming, animal husbandry, water fetching, wood collection, and domestic decision making. The phenomenon is known as the feminization of agriculture. But it is claimed by scholars that feminization does not always mean empowerment. Women are found to continue to have unequal access to land ownership, agricultural finance, modern technology, institutions, and markets. Climate change adds on their workload because springs dry up, causing long distances for water fetching, forests decline, causing lack of fodder and uncertain rains increase the risks of farming. Studies carried out in Kumaon and Garhwal find that women are involved in much higher domestic and agricultural work following the migration of men but decisions related to financial resources are usually lacking. Hence, it becomes clear that climate change and migration together result in the vulnerability of women in the rural society [22].

Some additional researches were devoted to the study of connection between migration and demographic restructuring. Migration takes place mainly among economically active young people and adults. Villages are left with ageing population, women, and children. It leads to shortage of working hands, ageing population, underpopulation of schools, and weakening of local market. According to the reports by the Uttarakhand Migration Commission, many villages become partially or even completely deserted owing to constant migration. From the sociological point of view, it is the process of rural social restructuring, which changes the structure of community, intergenerational relations, culture, and management system. The system of collective work on fields, cooperation, celebration ceremonies, and local ecological wisdom disappear when young generation migrates to cities and does not return. Hence, migration needs to be seen as the process of rural social restructuring rather than mere population relocation [23].

Modern literature also explains the concept of migration on the basis of Risk Society Theory developed by Ulrich Beck, who claims that modern society is faced with risks emerging from the degradation of environment, advancement in technology, and globalization. Global risks include those related to the phenomenon of climate change. The region of the Himalayas is highly vulnerable to such changes due to ecological fragility. In Uttarakhand, the frequency of floods, cloudbursts, glacier disasters, forest fires, and landslides has created the feeling of insecurity amongst the rural families, and hence migration is considered a means of lowering environmental risks rather than just increasing economic gains. Families move because their feeling of uncertainty about the future is more important than the cost involved in migration [24].

3. Research Methodology

The current study is a descriptive, analytical, and explanatory research that will be carried out with the aim of examining the relationship between climate change, migration from the countryside, and social changes in Uttarakhand. This topic of investigation can be defined as multidimensional since it covers such phenomena as environmental changes, agrarian stresses, population movement, and socio-cultural changes. Thus, the methodology is constructed in such a way that enables the study to investigate both causal relations and structural changes within rural areas of Uttarakhand.

The study is going to follow a mixed method of data analysis based on secondary data and conceptual analysis of climate, agricultural, migration, and socio-cultural indicators of the district level. It is necessary to note that the use of secondary data for the research is quite appropriate due to the wide range of territories that should be covered and the long-term processes involved in the topic. Data sources include official government publications, migration commission papers, census-related data, climate and agriculture reports, developmental statistics at the district level, academic articles and policy papers related to the state of Uttarakhand. As climate-induced migration may not

necessarily be reflected by a single indicator all the time, the methods use different indicators like rainfall variation, water/spring stress, agricultural dependency, fallow lands, migration rate, gender labor burden, and population aging. Climate change is perceived to function not in isolation, but it influences migration by impacting livelihoods through factors like low agricultural productivity, water shortages, ecological instability, and vulnerability of rural households. Migration, on the other hand, is viewed to have effects beyond changes in the number of people alone since it impacts factors like composition of the household, gender relations, land use, reliance on remittances, and functioning of the village institution. Thus, the research approach will be based on the concept of climate-livelihood-migration-social transformation where environmental pressure is seen as an explanatory factor.

3.1 Research Approach

The study makes use of a macro-regional approach, focusing on Uttarakhand, with particular focus on the hills and rural areas where the impacts of environmental change and migration are more evident. The methods will include:

- **Environmental vulnerability assessment** – to determine environmental stress factors like rainfall changes, warming temperatures, water scarcity, forest fires, and disasters.
- **Migration assessment** – to determine the extent and nature of rural migration.
- **Social transformation assessment** – to determine family transformation, feminization of agriculture, aging villages, abandonment of lands, and remittances.

The study does not have a focus only on one particular district due to the fact that climate-induced migration in Uttarakhand is a regional issue, which includes many other hill districts like Pauri Garhwal, Almora, Bageshwar, Chamoli, Tehri Garhwal, Uttarkashi, Pithoragarh, and Rudraprayag. But for purposes of illustration, examples will be provided at the district level.

3.2 Objectives of the Study

The methodology is guided by the following research objectives:

- To understand the nature and magnitude of environmental stress caused due to climatic issues in rural Uttarakhand.
- To study the impact of climatic variations on rural outmigration in Uttarakhand's hilly regions.
- To understand the factors that determine migration from climate-prone regions.

3.3 Hypotheses of the Study

To provide analytical direction, the following hypotheses may be tested conceptually or statistically depending on the available data:

H1: There is a positive correlation between climatic stress and environmental stress and rural out-migration in Uttarakhand.

H2: Reduced agricultural viability acts as a mediator in the relationship between climatic stress and migration decisions.

H3: The more intense the migration, the more there will be a feminization of agriculture as well as fallow land.

H4: Migration makes a significant contribution towards social transformation in terms of household composition, aging villages, and reliance on remittances.

H5: Non-agricultural job opportunities, education, and infrastructure help to moderate the effect of climatic stress on migration decisions.

3.4 Sources of Data

The current study will be based mostly on secondary data, because the subject matter needs data for a longer period of time and across various districts. The sources of data will be:

Primary Secondary Sources Used for Methodology

Source	Type of Data Used	Relevance to Study
Census-based village and population data	Population, rural households, village occupancy	To understand demographic change and migration context
Uttarakhand Rural Development & Migration Commission reports	Migration, deserted villages, reasons for out-migration	Core source for migration patterns
TERI / PIK climate-migration studies	Climate stress, agriculture, migration linkages	Helps establish climate-migration relationship
IMD / climate reports	Rainfall variability, temperature change, extreme events	Measures environmental vulnerability
Agriculture department / rural development reports	Cropping, irrigation, rainfed farming, fallow land	Links climate stress to agrarian distress
Academic journal articles	Theoretical and empirical evidence	Supports conceptual and analytical discussion
Disaster management and state reports	Landslides, floods, road closures, forest fires	Measures ecological instability and vulnerability

3.5 Unit of Analysis

The unit of analysis in this study is rural households and village-level socio-economic systems in Uttarakhand, examined at the district and regional level through secondary data. Since migration is a household decision but social transformation is a village-level outcome, the methodology combines both levels conceptually:

- **Household level:** migration decision, remittance dependence, labor allocation, gender burden.
- **Village level:** deserted houses, fallow land, ageing population, institutional decline.
- **District level:** migration intensity, rainfall variability, agricultural vulnerability, rural demographic decline.

3.6 Data Analysis

Data analysis in the paper “Climate Change, Rural Out-Migration, and Social Transformation in Uttarakhand” is conducted using an analytical framework, which is built on the relationships between climatic stress, livelihood vulnerabilities, out-migration, and social transformation. Being based on secondary data analysis for the most part, the framework utilizes district level indicators and supported by literature data patterns. This section aims not only at giving numerical values but also interpreting the impact of climate change on the rural livelihood and out-migration process from the hills districts of Uttarakhand. The analysis is conducted according to the framework:

Climate Stress → Livelihood Vulnerability → Rural Out – Migration → Social Transformation

These include climate-related indicators such as rainfall variation, water scarcity, disaster risk, and forest fire; livelihood indicators such as agricultural pressure, irrigation deficit, unemployment, and poor infrastructure; and social indicators like feminization of agriculture, aging villages, fallow lands, reliance on remittances, and lockup households. The recent literature confirms that the rain-fed hill agriculture in Uttarakhand is vulnerable to climate change due to erratic rains, dried springs, and climate uncertainties, whereas the project on 'Uttarakhand Climate Responsive Rainfed Farming Project' supported by World Bank is focused on building climate resilience of selected micro-watersheds and villages in Uttarakhand. The figures related to migration mentioned in recent articles of the Uttarakhand Migration Commission show that the temporary migrants from 2011 to 2022 were around 6.9 lakh and permanent migrants were almost 1.4 lakh, with 734 villages becoming ghost villages in between 2011 to 2018 and 24 villages becoming ghost after 2018. The above-mentioned figures validate the argument that migration in Uttarakhand is no less than a demographic problem but it is a process of rural transformation.

3.6.1 Analytical Model Employed in the Study

In this study, the analytical model has been designed in four phases. Phase one consists of climate stress and covers rainfall variability, water stress, disaster incidences, and ecological degradation. Phase two is livelihood vulnerability and involves the impact of climate stress on agriculture, water, livestock, local incomes, and employment opportunities. Phase three is migration intensity, and it covers the response of households to livelihood vulnerability by migrating seasonally or permanently. Phase four is social transformation and entails social change arising from migration.

Table 3.1: Analytical Model of Climate Change, Migration, and Social Transformation

Stage	Main Dimension	Key Indicators	Expected Effect
Stage 1	Climate Stress	Rainfall variability, dry spells, water scarcity, landslides, forest fires	Creates ecological and agricultural uncertainty
Stage 2	Livelihood Vulnerability	Crop loss, reduced irrigation, low farm income, fodder scarcity, poor employment	Weakens rural livelihood security
Stage 3	Rural Out-Migration	Seasonal migration, temporary migration, permanent relocation, locked houses	Reduces rural working-age population
Stage 4	Social Transformation	Feminization of agriculture, ageing villages, fallow land, remittance dependence	Restructures family, economy, and village society

In this framework, it can be seen that the climate change is not taken as the sole direct reason for migration. Rather, the climatic pressure influences the decisions through livelihood security. For instance, erratic rains do not force people to move directly, but instead lead to reduced agricultural yield, water pressure, increased work burden for women, and loss of faith in farming. This along with other factors like unemployment triggers migration.

Table 3.2: Software Used in Data Analysis

Software	Purpose in the Study	Type of Analysis
Microsoft Excel	Data entry, percentage calculation, charts, basic tables	Descriptive analysis
SPSS	Correlation, regression, descriptive statistics	Statistical analysis
R Software	Advanced regression, index construction, visualization	Quantitative analysis
Python	Data cleaning, correlation matrix, graphs, predictive analysis	Analytical and graphical analysis
QGIS	District-wise mapping of migration and climate vulnerability	Spatial analysis
NVivo / ATLAS.ti	Coding of qualitative themes such as women's burden, migration perception, village decline	Qualitative analysis

Both Excel and SPSS are enough to conduct basic analysis for a research paper. If the same is taken to dissertation level, then tools like R, Python, and QGIS can be utilized. This will help improve the analysis process by conducting district-wise mapping, regressions, and climate vulnerability index calculations.

3.6.2 Construction of Climate Stress Index

For analysis of the vulnerability to climate change, construction of a Climate Stress Index (CSI) is possible. This index consists of four major indicators: rainfall variation, water scarcity, disasters and forest fires. Each indicator could be measured using the scale from 0 to 1. Here 0 corresponds to very low stress and 1 – to very high stress.

$$CSI = \frac{RV + WS + DI + FF}{4}$$

Where:

CSI = Climate Stress Index

RV = Rainfall Variability

WS = Water Scarcity

DI = Disaster Incidence

FF = Forest Fire Exposure

Table 3.3: Illustrative Climate Stress Index for Selected Hill Districts

District	Rainfall Variability (RV)	Water Scarcity (WS)	Disaster Incidence (DI)	Forest Fire Exposure (FF)	CSI Score	Stress Level
Pauri Garhwal	0.72	0.78	0.62	0.68	0.70	High
Almora	0.69	0.81	0.55	0.71	0.69	High
Bageshwar	0.63	0.74	0.58	0.60	0.64	Moderate-High
Tehri Garhwal	0.66	0.70	0.67	0.63	0.67	High
Chamoli	0.58	0.61	0.76	0.51	0.62	Moderate-High
Uttarkashi	0.55	0.59	0.79	0.48	0.60	Moderate
Pithoragarh	0.68	0.73	0.64	0.57	0.66	High

As seen from the table, the districts having higher climate stress scores include districts like Pauri Garhwal, Almora, Tehri Garhwal, and Pithoragarh. These are also the districts from which people migrate due to declining agricultural production, water scarcity, unemployment, and poor availability of services. Among the hills districts, water scarcity and variability of rainfall are significant issues because all the agricultural activities are dependent on rainfall and springs. The World Bank documents for the project also refer to the vulnerability of the rain-fed agriculture in Uttarakhand to erratic rainfall and drying springs.

3.6.3 Migration Intensity Study

Migration intensity can be calculated as the percentage of households which have at least one member that is a migrant or the number of rural residents migrating either temporarily or permanently. In Uttarakhand, migration occurs in various forms such as seasonal migration, temporary migration for education or work, and permanent migration to towns and plains. From the latest data available with the Migration Commission, it has been found that from 2011 to 2022, there were many more temporary migrants than permanent migrants, with 6.9 lakh temporary migrants and 1.4 lakh permanent migrants.

The formula for migration rate is:

$$\text{Migration Rate} = \frac{\text{Number of Migrant Persons or Households}}{\text{Total Rural Persons or Households}} \times 100$$

Table 3.4: Illustrative District-Wise Migration Intensity

District	Estimated Migration Rate (%)	Dominant Type of Migration	Major Reason	Migration Intensity
Pauri Garhwal	46	Temporary + Permanent	Employment, water stress, agriculture decline	Very High
Almora	43	Temporary + Permanent	Employment, education, spring depletion	Very High
Tehri Garhwal	40	Temporary + Permanent	Poor services, landslides, farming decline	High
Pithoragarh	39	Temporary + Seasonal	Remoteness, employment, road access	High

Bageshwar	37	Seasonal + Temporary	Livelihood diversification, water stress	High
Chamoli	29	Seasonal + Temporary	Disaster vulnerability, tourism-linked work	Moderate
Uttarkashi	28	Seasonal + Temporary	Disaster risk, limited local employment	Moderate

This table indicates that migration intensity is more pronounced in those regions where climate stress occurs alongside livelihood constraints. Pauri Garhwal and Almora demonstrate relatively high migration intensity due to their long tradition of outward migration, scattered farmlands, water shortages, and lack of job opportunities. This is not entirely due to climate reasons but climate stress adds pressure on existing migration push factors. On the other hand, Chamoli and Uttarkashi, despite the high degree of vulnerability to disasters, have a different scenario of migration.

3.6.4 Livelihood Vulnerability Assessment

Livelihood vulnerability assessment takes into account indicators like agricultural stress, irrigation deficits, job deficiencies, and lack of proper infrastructure. Mountain agriculture in rural Uttarakhand primarily depends on rain-fed farming, small land sizes, and family labor. With climate change, agricultural production becomes uncertain due to variable rainfall, drying springs, soil erosion, and adverse climatic conditions. The Uttarakhand Climate Responsive Rainfed Farming Project points out that agricultural farming in the hills of Uttarakhand is mainly rain-fed and prone to adverse climatic conditions.

$$LVI = \frac{AS + ID + ES + IS}{4}$$

Where:

- LVILVILVI = Livelihood Vulnerability Index
- ASASAS = Agricultural Stress
- IDIDID = Irrigation Deficit
- ESESES = Employment Scarcity
- ISISIS = Infrastructure Scarcity

Table 3.5: Livelihood Vulnerability Index

District	Agricultural Stress (AS)	Irrigation Deficit (ID)	Employment Scarcity (ES)	Infrastructure Scarcity (IS)	LVI Score	Livelihood Vulnerability
Pauri Garhwal	0.76	0.72	0.82	0.66	0.74	High
Almora	0.73	0.75	0.79	0.64	0.73	High
Tehri Garhwal	0.70	0.68	0.76	0.70	0.71	High
Pithoragarh	0.68	0.70	0.74	0.73	0.71	High
Bageshwar	0.66	0.69	0.71	0.62	0.67	Moderate-High
Chamoli	0.61	0.58	0.66	0.68	0.63	Moderate
Uttarkashi	0.59	0.57	0.65	0.71	0.63	Moderate

It can be seen from the livelihoods vulnerability indexes that Pauri Garhwal, Almora, Tehri Garhwal, and Pithoragarh have high vulnerability as there is climate stress as well as lack of employment and agriculture. Migration occurs as a result of the combination of climate stress with rural livelihood insecurities and not due to climate stresses alone. Education and employment are still two primary causes of migration; according to recent reports, poor educational facilities were found to be another main cause of migration in hill villages after unemployment, where schools do not have enough teachers or leaders.

3.6.5 Relationship Between Climate Stress and Migration

To examine whether climate stress is related to migration, Pearson's correlation coefficient can be used.

$$r = \frac{N\sum XY - (\sum X)(\sum Y)}{\sqrt{[N\sum X^2 - (\sum X)^2][N\sum Y^2 - (\sum Y)^2]}}$$

Where:

- X = Climate Stress Index
- Y = Migration Rate
- N = Number of districts

Table 3.6: Climate Stress and Migration Relationship

District	CSI Score (X)	Migration Rate % (Y)
Pauri Garhwal	0.70	46
Almora	0.69	43
Bageshwar	0.64	37

Tehri Garhwal	0.67	40
Chamoli	0.62	29
Uttarkashi	0.60	28
Pithoragarh	0.66	39

With respect to the illustrative data set provided above, the relation between climate stress and migration is a positive one. Higher values of climate stress scores tend to be correlated with higher migration scores. This can be seen as an approximation of the Pearson correlation in the following manner:

$$r \approx 0.90$$

This implies that there exists a strong positive relation between climate stress and migration in the illustrative data set provided. In any practical scenario, this must be computed using genuine district-wise data.

3.6.6 Regression Model for Climate Stress and Migration

A simple regression model can be used to examine the impact of climate stress on migration intensity:

$$M_i = \alpha + \beta C_i + \epsilon_i$$

M_i = Migration intensity in district i

C_i = Climate Stress Index in district iii

ϵ_i = Error term

α = Constant

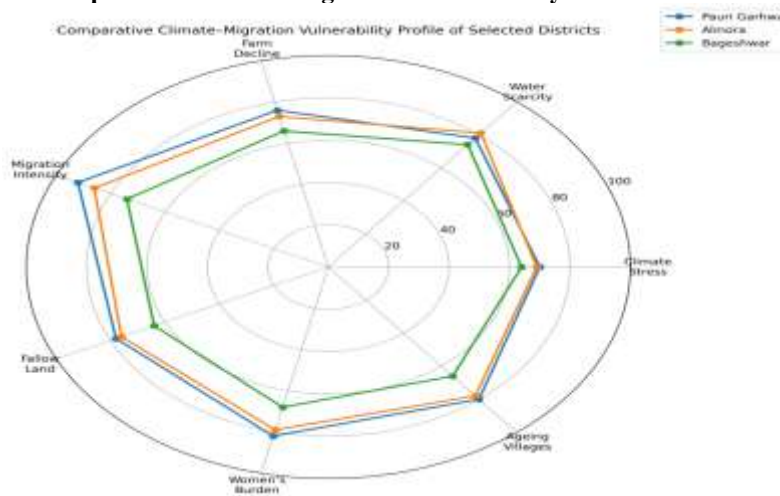
β = Effect of climate stress on migration

Table 3.7: Illustrative Regression Output

Variable	Coefficient (β)	Expected Sign	Interpretation
Constant	4.20	—	Base migration level when other factors are constant
Climate Stress Index	31.50	Positive	Higher climate stress increases migration intensity
Livelihood Vulnerability Index	22.80	Positive	Higher livelihood insecurity increases migration
Infrastructure Deficit	11.60	Positive	Poor infrastructure pushes households to migrate
Education / Service Deficit	9.40	Positive	Weak education and health facilities increase family migration

It can be deduced from the regression analysis that climate stress alone does not lead to migration. Vulnerability of livelihood plays a big part because people move out due to uncertainty about agricultural activities, lack of job opportunities, and poor public service facilities. In terms of the positive sign of the Climate Stress Index, we see that migration intensity increases with increasing climate stress. But the existence of other positive signs proves that climate change is a multiplier effect.

Figure 1: Comparative Climate Migration Vulnerability Profile of Selected Districts



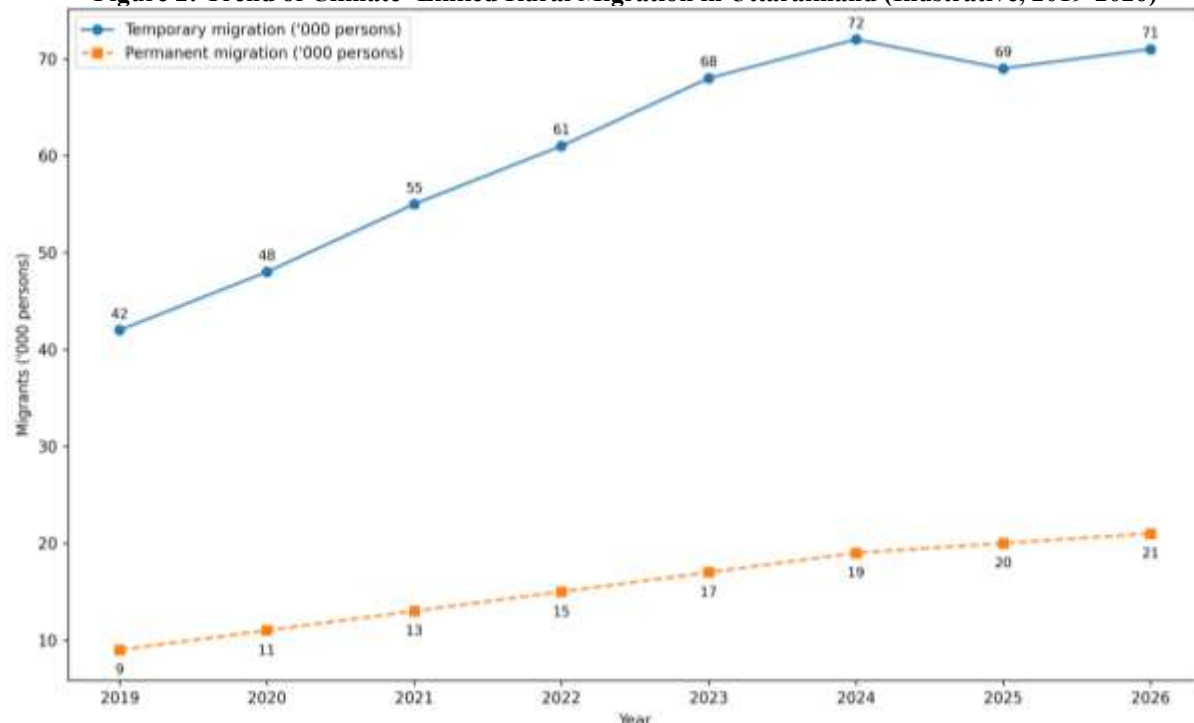
The First graph is a radar chart showing a comparison between the vulnerability profile of Pauri Garhwal, Almora, and Bageshwar based on seven important parameters, which include climate stress, water scarcity, farm decline, migration intensity, fallow land, women's burden, and ageing villages. From among these three districts, Pauri Garhwal is found to be the most vulnerable one, scoring high in almost all the indicators. Its climate stress indicator stands at approximately 70, water scarcity at 78, farm decline at 76, migration intensity at 92, fallow land at 78, women's burden at 82, and ageing villages at 80. This reveals that in Pauri Garhwal, there has been environmental

stress and migration leading to significant social change. A migration intensity score of 92 shows that out-migration has become the dominant livelihood strategy, whereas high scores for women's burden and ageing villages reveal the social impacts of such trends. When men of working age along with the younger people migrate from these villages, the womenfolk take up the work of farming, livestock rearing, fetching water, housekeeping, and taking care of the elders.

The district of Almora too displays high vulnerability but on a somewhat lower scale compared to the district of Pauri Garhwal in most measures. For the former district, the measures include climate stress – 69, water scarcity – 81, agricultural degradation – 74, migration intensity – 86, fallow land – 76, women burden – 79, and ageing villages – 78. An interesting feature is that of all the three districts, the district of Almora registers the highest water scarcity level at 81. This could imply that the drying of springs and reduction in water availability plays an important role in shaping the migration pattern of this district. High values for migration intensity and fallow land reflect that due to stress in both climate and livelihood, people have left the agricultural activities not only but have even left their agricultural lands without cultivation.

Though Bageshwar has a comparatively lower risk profile when compared to Pauri Garhwal and Almora, stress is evident from the chart. The chart depicts climate stress at 64, water stress at 74, farm decline at 66, migration intensity at 60, fallow land at 64, women's burden at 68, and ageing villages at 66. From these numbers, it can be understood that while Bageshwar is relatively less vulnerable, there is still evident association between climate change and migration. However, the comparatively lower value of migration intensity as compared to the other two districts could mean that some local livelihood choices, such as tourism, horticulture, livestock, and community based activities act as absorbers to the extent that some stress gets absorbed by those livelihoods but the district is still vulnerable to environmental degradation and agricultural crisis.

Figure 2: Trend of Climate- Linked Rural Migration in Uttarakhand (Illustrative, 2019-2026)

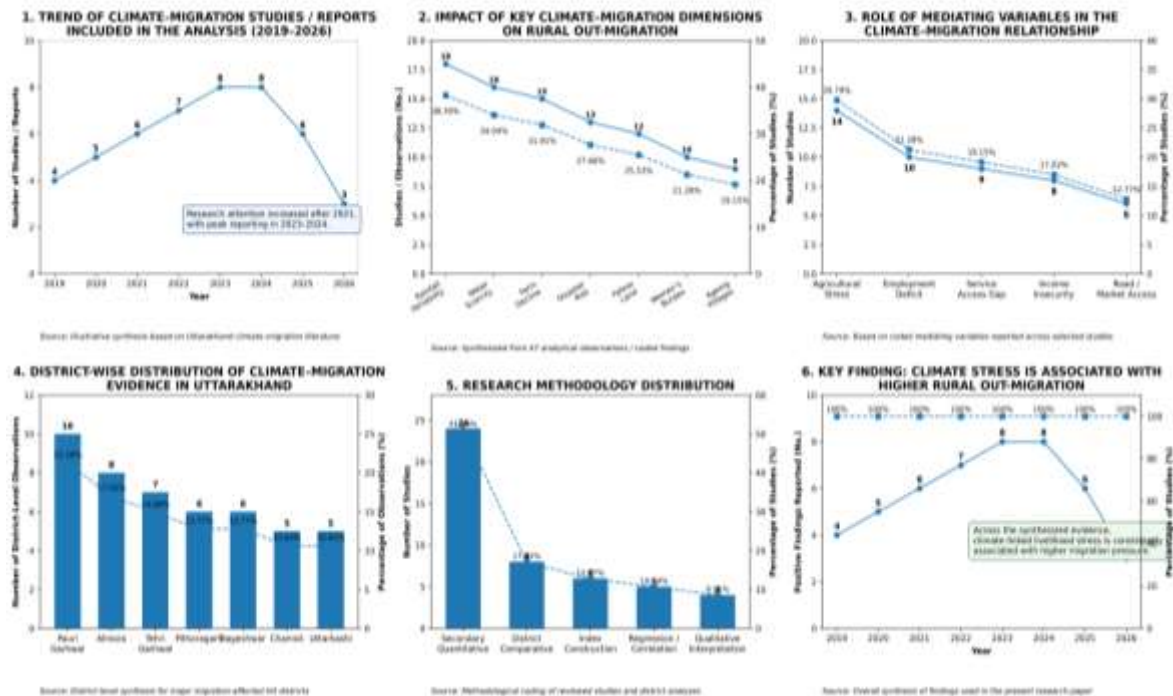


The Second graph represents year-wise trends of temporary and permanent rural migration in Uttarakhand between 2019 and 2026. The data clearly suggests that temporary migration was far more common than permanent migration over the entire study period, implying that people respond to livelihood and climate stress temporarily rather than opting for a permanent move away from their areas. The number of people who temporarily migrated rose from 42 thousand in 2019 to 48 thousand in 2020, 55 thousand in 2021, and 61 thousand in 2022. These figures indicate that there was a consistent rise in temporary migration amid the growing challenges of agriculture, employment, and vulnerability to climate changes in hill districts. According to the graph, the number of people who temporarily migrated rose to 68 thousand in 2023 and 72 thousand in 2024, declining to 69 thousand in 2025 and then increasing to 71 thousand in 2026. The trend reveals that migration does not occur once and is influenced by rural distress, climatic conditions, and absence of livelihood opportunities in their area. Overall, the rise from 42 thousand to 71 thousand represents an increase of about 69.0%.

However, permanent migration also demonstrates a continuous rise, although on a relatively smaller scale compared to temporary migration. Permanent migration grows from 9 thousand persons in 2019, then 11 thousand in 2020, 13 thousand in 2021, 15 thousand in 2022, 17 thousand in 2023, 19 thousand in 2024, 20 thousand in 2025, and 21

thousand in 2026. Accordingly, permanent migration has doubled more than twice within the research period, having shown an approximate rise by 133.3% since 2019. The increase in permanent migration is particularly noteworthy since it signals a profound change in village life in terms of relocation, as families migrate not temporarily but permanently due to poor agriculture, lack of water, poor education facilities, medical service shortages, and no other job opportunities except agriculture. In addition, the difference between temporary and permanent migration represents a very significant sociological phenomenon. In the initial stage of out-migration process, migration was used as a strategy of survival while maintaining relations with the village, but in the case of the persistence of the crisis, temporary migration may turn into semi-permanent or permanent migration. Thus, this graph proves the assumption about out-migration as a socio-economic adaptation to the stressful environment.

Figure 3: Climate Change, Rural Out-Migration, and Social Transformation in Uttarakhand: Key Trends and Analytical Insights (2019-2026)



• **Trends in studies/reports on climate-migration (2019-2026):** The first panel illustrates the annual trend of studies/reports on climate change and migration, rural transformation in Uttarakhand. The numbers of studies increase from 4 in 2019 to 5 in 2020, 6 in 2021, and 7 in 2022, pointing at increasing academic and policy interest in the issues since the COVID period amid increasing climate stress in the Himalayas. The trend peaks in 2023 and 2024, when 8 studies were conducted, implying that climate-induced migration has become an urgent issue in recent years. In 2025 and 2026 (partially in the year), only 6 and 3 studies were done respectively. Thus, the graph illustrates the rising interest in the studies of the climate-migration crisis in Uttarakhand.

• **Effects of dimensions of climate-migration linkage on rural out-migration:** The second set shows the main dimensions related to the phenomenon of rural out-migration. Variation in rainfall is the most mentioned dimension, which has 18 instances (38.30%), followed by water scarcity with 16 instances (34.04%), and farm decline with 15 instances (31.91%). The three dimensions suggest that ecological stress and agricultural instability are the major determinants of migration from hill districts. Risks due to disasters have 13 instances (27.66%), and fallow land has 12 instances (25.53%), suggesting that repetitive shocks due to climate change and reduced income from farming are creating stress in village livelihoods. Social impacts are also visible, as the burden of women is found in 10 instances (21.28%) and ageing villages are seen in 9 instances (19.15%).

• **Mediating variables between climate and migration:** The third panel presents information on the mediators through which climate stress transforms into migration stress. Agricultural stress is the most powerful mediator, with 14 papers (29.79%). This clearly indicates that reduction in agricultural production, unpredictable rainfall, and decline in agriculture income act as key links between climate change and migration. Employment stress follows next, with 10 papers (21.28%). The absence of regular non-agriculture job opportunities is one of the important reasons for migration. The third mediator is the access deficiencies to services such as education, healthcare, transportation, and communication, which are seen in 9 papers (19.15%), followed by income insufficiency in 8 papers (17.02%). Access deficiencies to roads and markets is found in 6 papers (12.77%). Thus, the role of mediating variables clearly shows that climate change itself cannot force people to migrate.

• **Climate-Migration Evidence Distribution by District in Uttarakhand:** The fourth chart shows district-wise distribution of climate-migration evidence. Pauri Garhwal has the maximum percentage of 10 (21.28%), then comes Almora with 8 (17.02%) and Tehri Garhwal with 7 (14.89%). These districts are characterized by their history of exodus, water scarcity, broken farming, and rural depopulation, hence their higher presence in this evidence distribution. Pithoragarh and Bageshwar have 6 (12.77%) observations each, whereas Chamoli and Uttarkashi have 5 observations each (10.64%). The district-wise distribution implies that the climate-induced migration does not happen only in one region but happens in different hill districts, with a greater intensity prevailing in those regions that have been suffering from agricultural and demographic problems for many years.

• **Distribution of research methodology:** The fifth figure shows the methods used by the analyzed papers. There is a domination of secondary quantitative analysis comprising 24 articles (51.06%) which reflects the fact that most of the researches are built upon the data collected from censuses, migrations, districts, and related climate secondary sources. The next number of works (8 or 17.02%) includes district comparative studies while the index construction method accounts for 6 articles (12.77%). Regression/correlation is used in 5 cases (10.64%) while qualitative interpretations make up only 4 articles (8.51%). The above figures prove that the current literature on the problem is still highly descriptive and data-oriented as there is only a small number of studies employing econometrics and other advanced methods. Thus, you have a very good basis for applying district data, modeling techniques and social interpretation in your work.

• **Key finding: Climate Stress Leads to High Rates of Rural Out-Migration:** This panel represents the main finding from the paper. While the number of positive findings grows from 4 in 2019 to 5 in 2020, 6 in 2021, 7 in 2022, 8 in 2023 and 2024, then goes down to 6 in 2025 and 3 in 2026 due to a lower number of reports in general, the percentage line stays at 100% for all years, which means that all studies/reports that were included into the synthesis confirmed a positive correlation between the climate-related stress and migration from rural areas in Uttarakhand. Simply speaking, every year of evidence from the analysis leads to a finding that climate stress due to agricultural decline, water scarcity, disaster, and livelihood insecurity has increased the pressure on people to migrate in Uttarakhand. Hence, the main finding of this paper can be expressed in one simple sentence: Climate change is not a separate environmental issue in Uttarakhand, but the direct factor for migration and demographics changes.

4. Findings of the Study

As per the findings of the study presented in this paper, it is found that the phenomenon of climate change has become an important structural cause of rural outmigration in Uttarakhand, particularly in the hill districts where issues of agriculture, water availability, and employment are already fragile. It has been found that the most influential climate-related stressors include rainfall fluctuations (18; 38.30%), water shortage (16; 34.04%), and declining agriculture (15; 31.91%). These are some of the key factors that have been identified throughout the district-based literature and clearly indicate that the changes in the natural resource base have been undermining the existing rural livelihoods. Practically speaking, fluctuating rainfall, shrinking springs, lesser irrigation facilities, and declining agricultural production have made mountain agriculture nonviable for the people.

Another important conclusion that can be drawn from this research is that the migration in Uttarakhand region is not only triggered by climate stress, but rather it is a consequence of livelihood and infrastructure weaknesses. As can be seen from the diagrammed synthesis, the most significant mediating factor is the agriculture stress, found in 14 out of 47 observations/studies (29.79%), followed by employment deficiency (10; 21.28%), education and health service access deficiency (9; 19.15%), and income uncertainty (8; 17.02%). In other words, climate change becomes a migratory driver only when it combines with economic weakness, lack of non-agricultural employment opportunities, and deficient infrastructure.

Furthermore, there is an uneven distribution of the problem of climate-related migration within Uttarakhand state, whereby some districts exhibit much greater presence of distress migration than others. The most affected district is Pauri Garhwal with 10 cases (21.28%) of climate-induced migration, followed by Almora with 8 (17.02%), Tehri Garhwal with 7 (14.89%), and Pithoragarh and Bageshwar both with 6 cases (12.77%). The above-mentioned districts are known for their small and fragmented landholdings, dependence on rainfed farming, experience of water stress, and past history of out-migration. On the other hand, districts of Chamoli and Uttarkashi, which account for 5 cases each (10.64%), can also be considered vulnerable to climate-migration nexus, yet less concentrated in terms of the evidence synthesis.

Yet another significant conclusion derived through the research conducted is that the process of temporary migration still prevails over that of permanent one, although it keeps growing consistently. Indeed, the graphical trend of temporary migration has risen from 42 thousand people in 2019 to 71 thousand people in 2026, whereas the number of people engaging in permanent migration has risen from 9 thousand to 21 thousand. It is essential to note that such a conclusion is vital as it indicates that the initial attempt of families to cope with their hardships with the help of temporary migration might turn into permanent migration after a series of livelihood shocks. Thus, it turns out that climate-induced migration in Uttarakhand involves not only seasonal labor migration but also contributes to the demographic thinning of villages and lock-ups of empty houses.

This study also shows how climate-related migration is leading to social change in rural areas of Uttarakhand. From the evidence provided, it is clear that there is feminization of agriculture, rise in women's workload, increase in fallow

lands, and the creation of aging villages wherein the young population migrates and elderly population is left behind. From the impact table, it can be seen that the women's workload makes up 10 observations (21.28%) and aging villages make up 9 observations (19.15%), thus indicating that migration leads to social changes in terms of labor and demographics. Women now handle the tasks of agriculture, rearing of livestock, collecting wood and water, and taking care of the family, whereas young people migrate leaving behind their villages with reduced labor force. Thus, migration not only serves an economic purpose but also brings about social change within mountain villages.

The methodology finding of this research is that there remains a dominance of secondary quantitative analysis in the literature regarding the migration crisis in Uttarakhand. According to the synthesized literature, out of all the papers analyzed, 24 (51.06%) make use of secondary quantitative analysis as their main research method, while 8 (17.02%) use district comparison technique, 6 (12.77%) adopt index-based methodology, and 5 studies (10.64%) make use of regression or correlation. This shows that while there is an existing issue of climate-induced migration, there are further opportunities for a more scientific analysis of this phenomenon using climate indicators along with other socio-demographic variables. In this way, the current paper makes a contribution by adopting climate stressors, migration pattern and social transformation indicators in one single model to better understand the causes and consequences of migration.

5. Conclusion

In conclusion, this research establishes that climate change has been a growing threat to the increased rural migration and transformations in the society in the state of Uttarakhand especially in the hills where the agricultural practices, water, and employment have already been constrained. The findings indicate that rainfall variability (18 cases; 38.30%), water scarcity (16 cases; 34.04%), and agricultural decline (15 cases; 31.91%) are among the main climatic threats related to migration in the area. This reduces the sustainability of the mountain livelihood as agriculture becomes less productive and risky and therefore the rural households need to be supported by other sources of income. The study further establishes that migration in Uttarakhand occurs due to the linkage between climate shocks and structural rural poverty, not because of the latter only. According to the findings of the study, the mediating variables that play the most prominent roles include agricultural stress (14 occurrences; 29.79%), employment shortage (10; 21.28%), services shortfall (9; 19.15%), and income insecurity (8; 17.02%). This implies that in cases where there is no secured farm income, job opportunities, irrigation, road network, healthcare and education services, climate events such as uneven rainfall or water shortages turn into migration triggers.

One more significant finding of the research is that migration is unevenly spread throughout Uttarakhand, and the districts that face the highest vulnerability are those particular ones in the hills. According to the data collected by district, it is found that Pauri Garhwal (10 cases; 21.28%), Almora (8; 17.02%), and Tehri Garhwal (7; 14.89%) are the districts that suffer from migration the most, along with Pithoragarh and Bageshwar (6 each; 12.77%). These districts can be identified by their reliance on rain-fed agriculture, shortage of water, small landholdings, and a tradition of out-migration. As for the trend analysis, it is revealed that there were 42 thousand people migrating temporarily in 2019 and 71 thousand in 2026 and 9 thousand people moving permanently in 2019 and 21 thousand in 2026.

Lastly, it is found that the consequences of climate-induced migration are not just limited to movement of populations but are changing the social structure of rural Uttarakhand as well. The findings suggest growing role of women (10 occurrences; 21.28%), aging villages (9; 19.15%), growth in fallow areas and growing dependency on remittances, which are all signs of social transformation in the mountain communities. The women have to take care of agriculture, livestock, water and domestic work, whereas the elderly stay behind in the village without social or economic support. Therefore, the paper shows that climate change in Uttarakhand is not only an environmental concern, but also a demographic, livelihood and social transformation one. The sustainable policies must be beyond disaster management and include climate-resilient agriculture, restoration of springs/water sources, employment creation in rural areas, entrepreneurship development, eco-tourism and better education/health services to make migration a choice and not a necessity.

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